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ACOUSTIC PROPAGATION LOSS AS A FUNCTION OF VARIATIONS IN SOUND VELOCITY PROFILE

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PREPARED BY

R. M. Lesser

K. R. Igelman

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FOREWORD

The research performed in this study was made possible by cooperation of the Navy Electronics Laboratory in allowing Lockheed to use the NEL computer programs translated under contract N123-(953)34195A. Special appreciation is expressed to Mr. M. A. Pedersen and Dr. E. R. Anderson of NEL for their helpful suggestions.

ABSTRACT

A study of the effects of sound velocity profile variations on acoustic propagation loss at a single location was made. This study utilized the computer programs developed at the Navy Electronics Laboratory for the CDC 1604 and subsequently translated to the IBM 7094 system at Lockheed. Four sound velocity profiles for Station "PAPA," lat. 50°N, long. 145°W were selected, two in summer and two in winter. Computed propagation losses for a 50-yard source depth, utilizing 25 receiver depths between the surface and 500 yards, exhibited significant differences among the profiles. Losses varied by as much as 30 db at comparable ranges and depths. These variations are related to major differences in the sound velocity profiles. The greatest difference was associated with the steep positive surface layer velocity gradient of one of the two winter profiles. Significantly less propagation loss resulted from this profile than from the other three studied.

CONTENTS

LIST OF ILLUSTRATIONS

Section 1

INTRODUCTION

For the past several years the Navy Electronics Laboratory has been developing automatic procedures for the theoretical computation of underwater acoustic propagation loss as a function of sound velocity profile[1, 2]. One of the basic assumptions in the NEL procedures is that no spatial or temporal change occurs in the sound velocity profile for the area and time under consideration. Forecasts of propagation loss have been made prior to experimental tests, and such forecasts have been highly successful in stable areas. However, in areas such as the Kuroshio regime where large spatial variations in sound velocity profile occur and in the Gulf of Alaska, where fairly rapid temporal changes occur, the forecasts have been somewhat less successful. This paper presents the results of a preliminary study of the effect on propagation loss of variations in sound velocity profile at a single location in the Northeast Pacific. Data from Ocean Weather Station "PAPA," located at lat. 50°N, long. 145°W, collected by the Pacific Oceanographic Group, Nanaimo, British Columbia were selected for this study. The computer programs developed at the Navy Electronics Laboratory and translated to the IBM 7094 Data Processing System by Lockheed were utilized.

The theory upon which this study is based and the computational procedures are not presented here as these were covered by Pedersen[1], Pedersen, Gordon, and Keith[2], Gordon[3], and Lesser and Igelman[4].

Section 2

SOUND VELOCITY PROFILES

Ocean Weather Station "PAPA" sound velocity profiles are characterized by both single and double velocity minima in all seasons of the year. Sound velocity computations performed for all seasons of the year from the Pacific Oceanographic Group data demonstrated this (for example References 5 and 6). For the purposes of this study four "typical" profiles were selected, two for the summer and two for the winter. Each season was characterized by one profile with a single minimum velocity and one with double minima. This choice of profiles provides extremes in surface velocity, duct gradient, duct depth, and minimum velocity configurations. Discrete sound velocities were computed from temperature, salinity, and depth utilizing the NEL program based on Wilson's equations[7]. The winter profiles are depicted in Figures 1 and 2. Summer profiles are depicted in Figures 3 and 4. All profiles exhibit surface ducts with winter depths of 75 to 125 yards and summer depths of 25 to 34 yards. The winter profile of Figure 2 exhibits a much stronger surface duct than that of Figure 1. The velocity gradient in Figure 2 is the result of a positive temperature gradient, while in Figure 1, the duct is isothermal. This will result in the trapping of more acoustic energy in the duct of Figure 2. The double minima occur at about the same depths in summer and winter, but the summer single minimum occurs at about 110 yards and the winter minimum near 420 yards. Thus the four profiles exhibit significantly different features which should result in markedly different acoustic propagation loss characteristics.

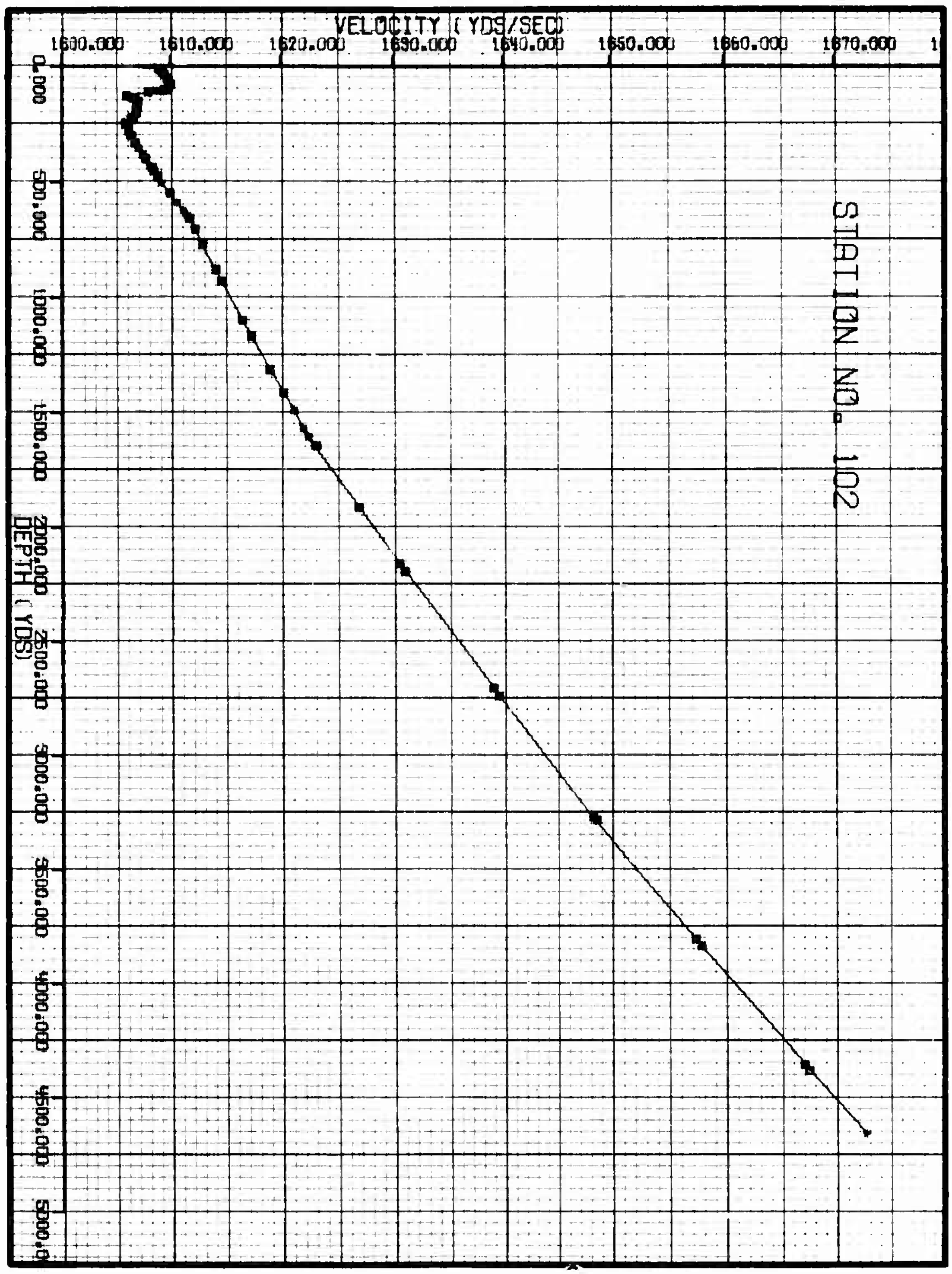

FIGURE 1 - WINTER SOUND VELOCITY PROFILE
DOUBLE MINIMUM

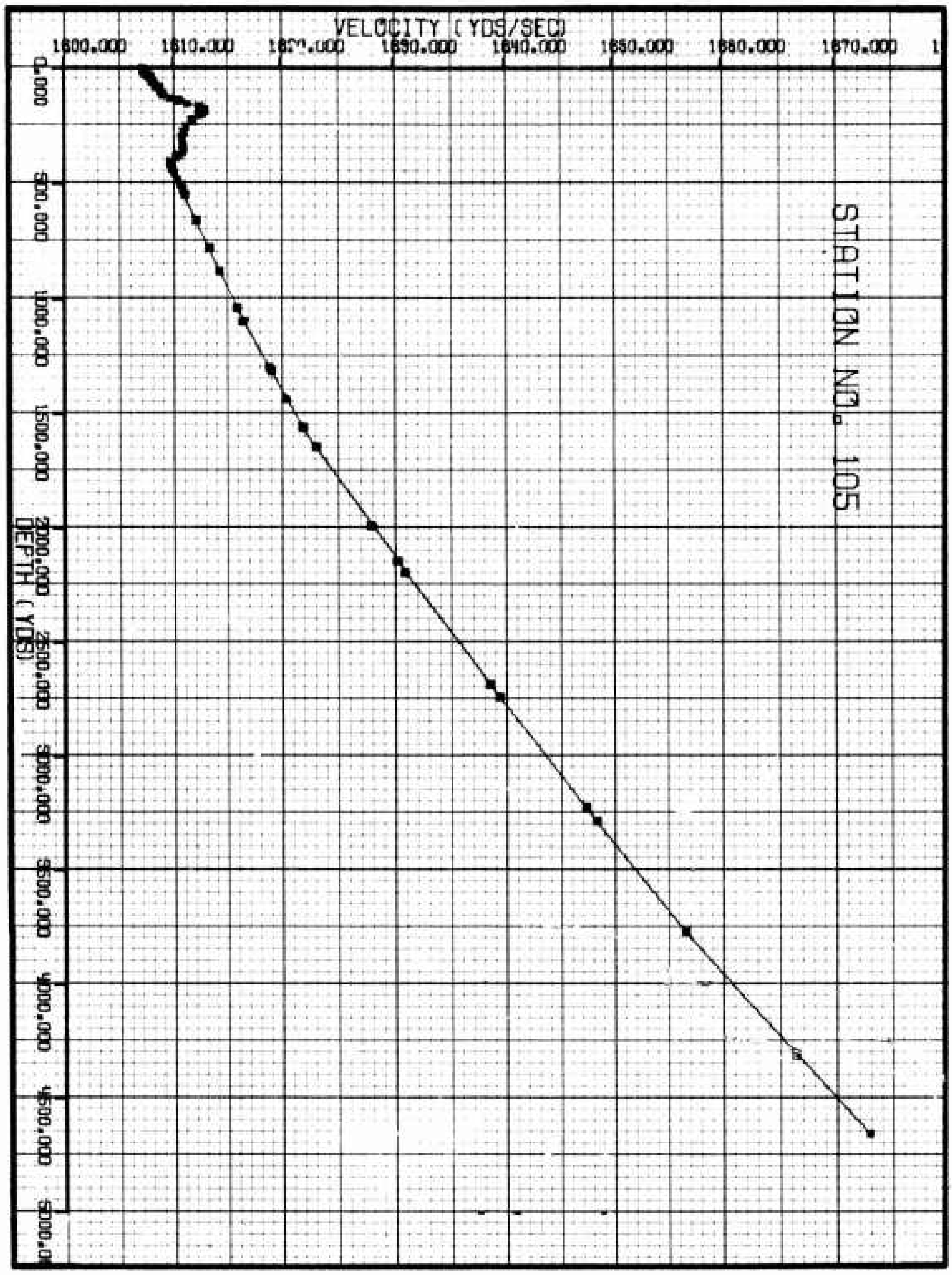

FIGURE 2 - WINTER SOUND VELOCITY PROFILE
SINGLE MINIMUM

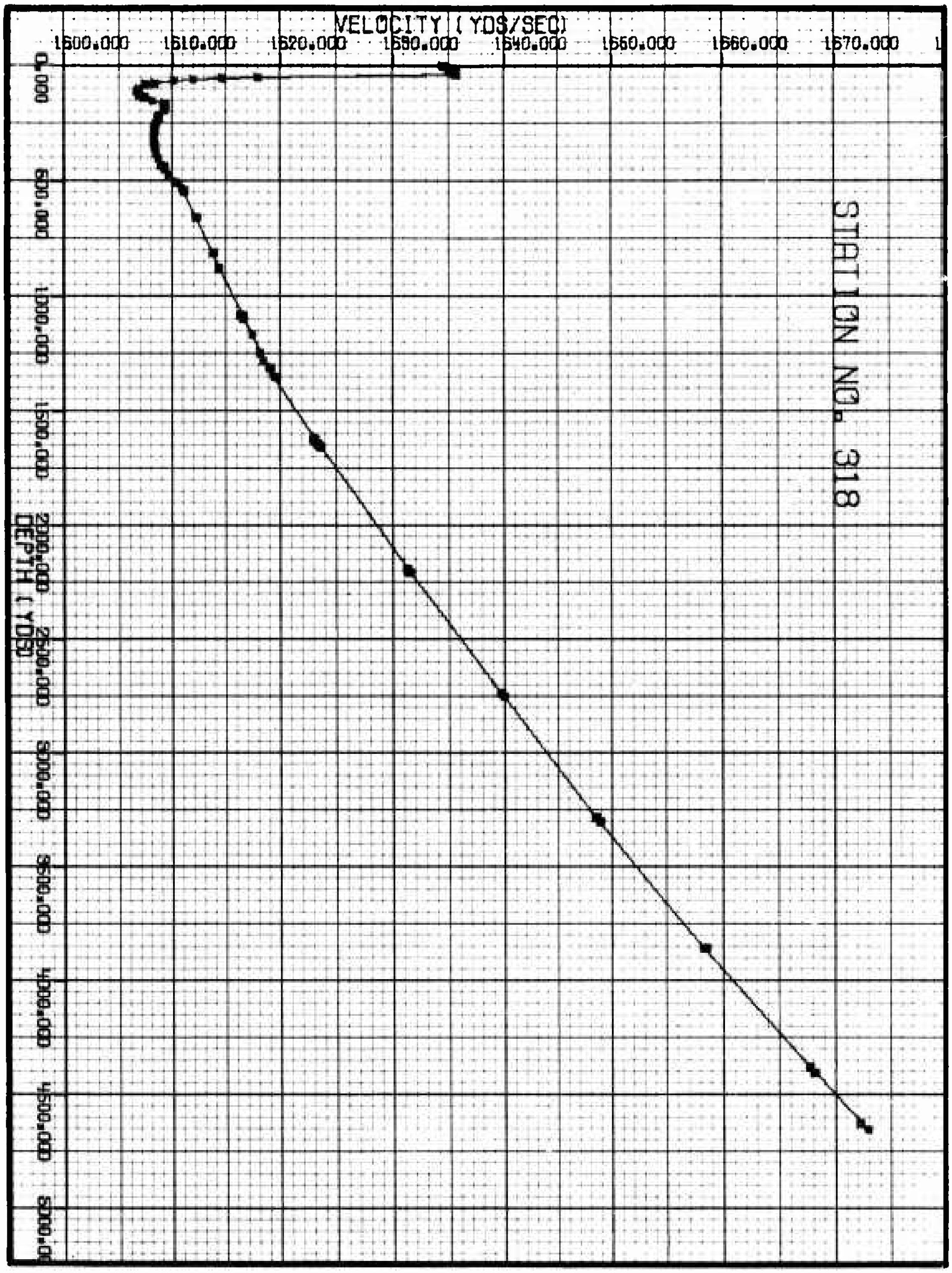

FIGURE 3 - SUMMER SOUND VELOCITY PROFILE
DOUBLE MINIMUM

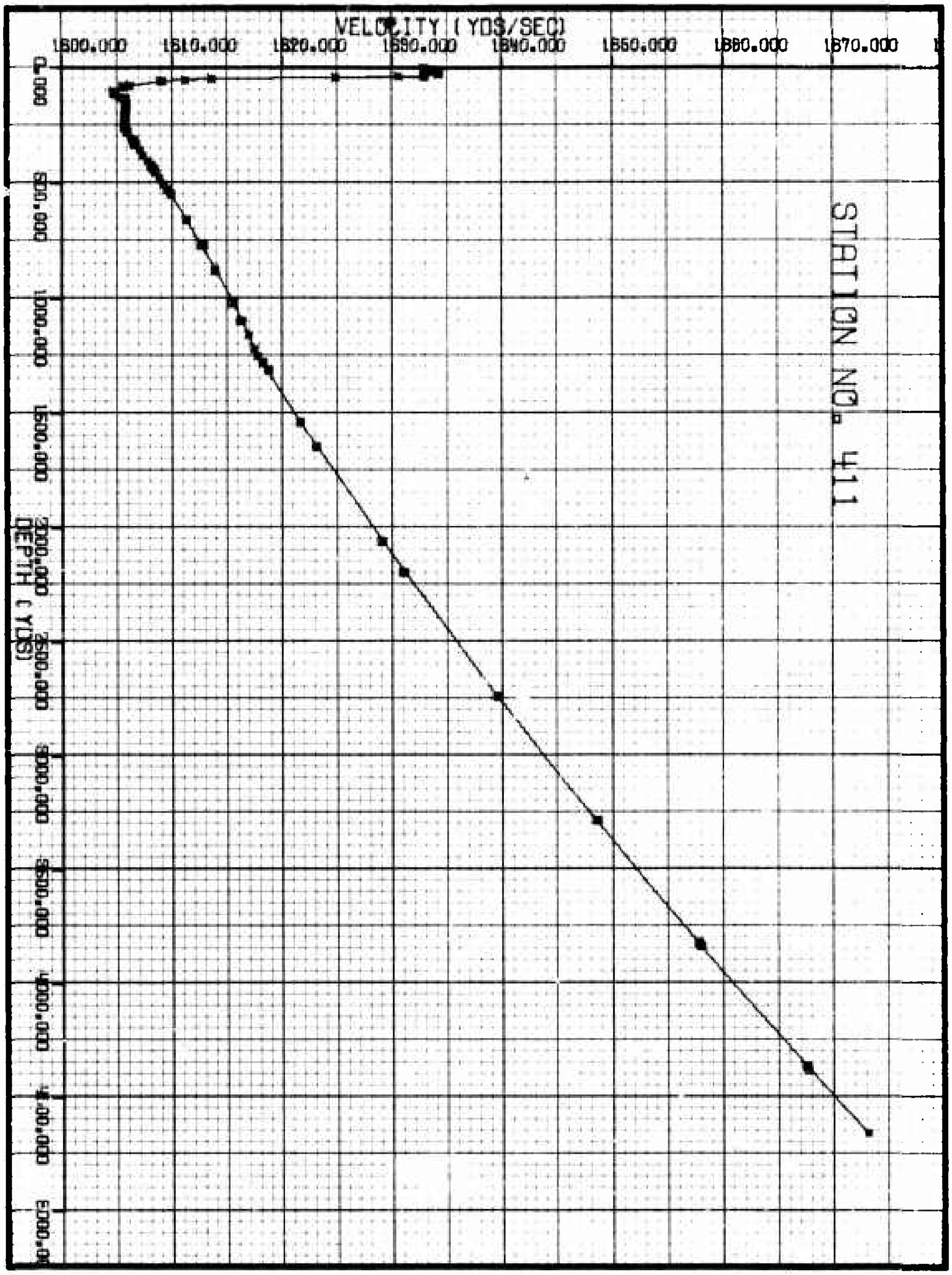

FIGURE 4 - SUMMER SOUND VELOCITY PROFILE
SINGLE MINIMUM

Section 3

PROPAGATION LOSS

Propagation losses were computed utilizing the IBM 7094 program described by Lesser and Igelman[4]. In order to facilitate direct comparison between sound velocity profiles, the same source depth (50 yards) was used in propagation loss computations for all profiles. Twenty-five receiver depths were utilized.

Figure 5 depicts the upper 500 yards of the propagation loss field for the winter sound velocity profile of Figure 1. The caustics of zones 1 and 2, at 27.5 and 56 kyds, respectively, are apparent at the surface. The caustics delineate the leading edge of increased intensity due to the presence of the zones. It should be noted that no complete shadow zones (loss > 100 db) occur in the first 180 kyds; however, several zones of reduced intensity (loss >90 db) do occur, primarily just ahead of the convergence zones. Figure 6 depicts the propagation loss field for the winter velocity profile of Figure 2. Several differences can be noted between Figures 5 and 6. The most striking difference is the insonified zone above 100 yards' depth which extends to beyond 160 kyds. This can be attributed to an extremely strong surface duct. The zonal caustics are not apparent above 100 yards' depth but do occur at about 30-kyd intervals below 100 yards. An additional feature which occurs in Figure 6 but not in Figure 5 is the presence of a full shadow zone (loss >100 db) at a range of about 60 kyds extending from a depth of 100 yards to about 400 yards, becoming almost obliterated below 400 yards. It is impossible to attribute specific features such as these to any particular feature of the sound velocity profile without further study of

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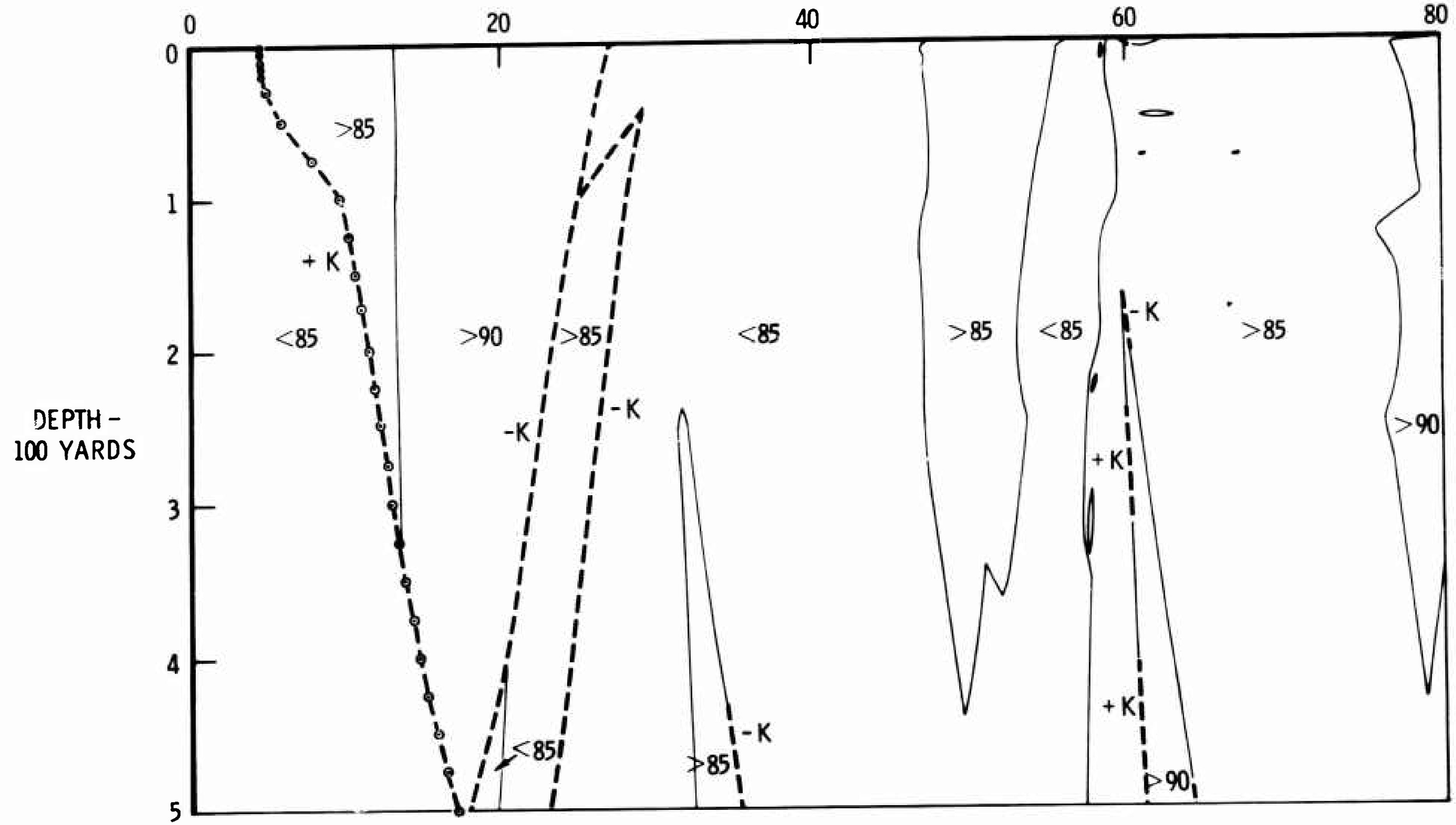

FIGURE 5 - PROPAGATION LOSS IN DB FOR PROFILE OF FIGURE 1, 50 YARD SOURCE DEPTH

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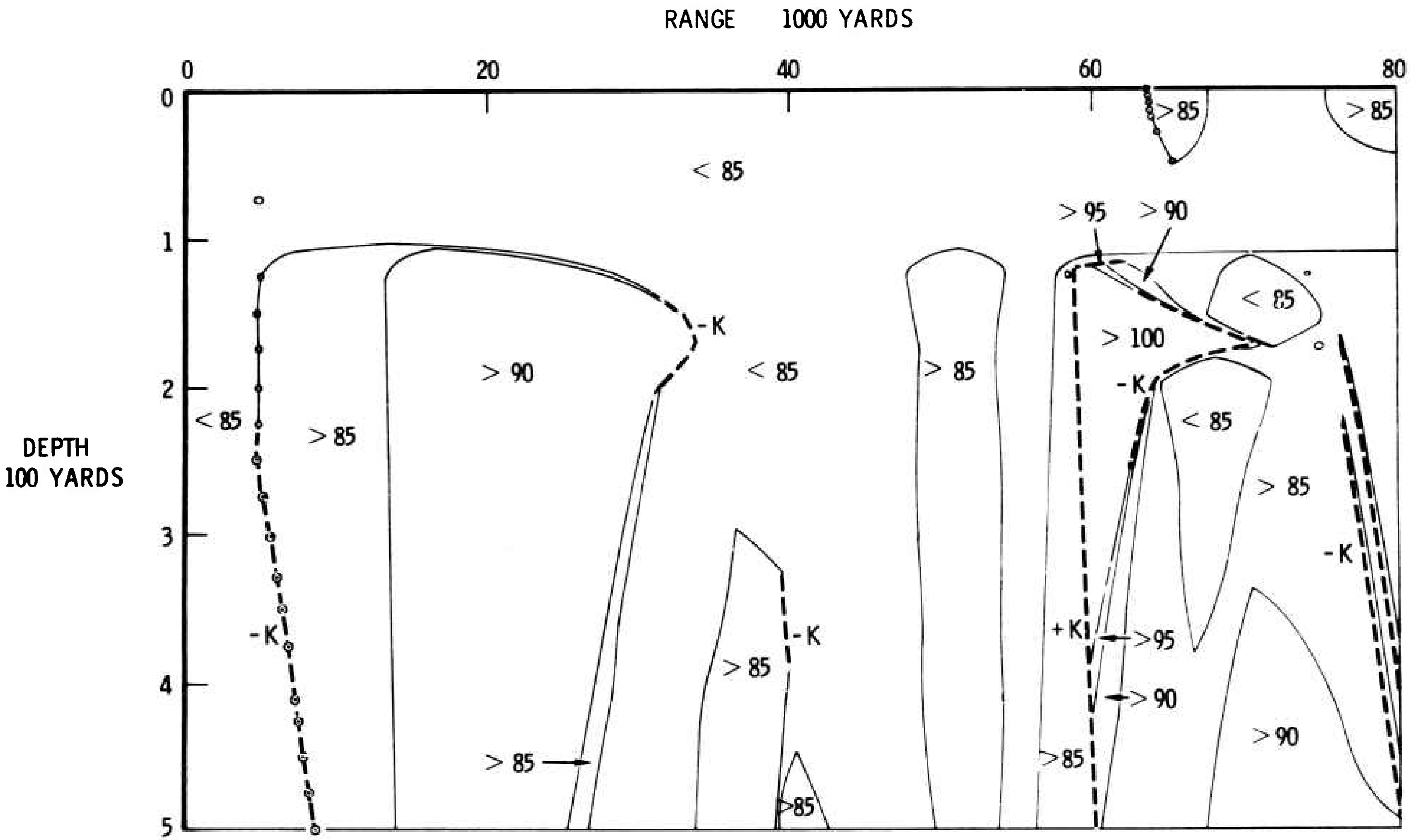

FIGURE 6 - PROPAGATION LOSS IN DB FOR PROFILE OF FIGURE 2, 50 YARD SOURCE DEPTH

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additional sound velocity profiles. It can be stated generally, however, that the major variations in Figures 5 and 6 can be attributed to differences in surface duct depth and velocity gradient as well as general differences below the duct.

Figures 7 and 8 depict the propagation losses for the summer profiles of Figures 3 and 4. Both loss charts exhibit a shadow zone (loss >100 db) at ranges between 60 and 80 kyds. However, Figure 7 depicts a loss area of greater than 100 db through the entire upper 500 yards in depth; Figure 8 does not. This difference can probably be attributed to the combination of the sharper thermocline and the double minimum depicted on the profile of Figure 3. The caustics which delineate the convergence zones in Figures 7 and 8 extend all the way to the surface. The first three zones are clearly delineated. A strong fourth zone is not predicted in either case.

The four propagation loss charts show significant differences in loss which are related to the differences in sound velocity profile. These differences are demonstrated more fully in Figures 9, 10, and 11 which depict detailed losses with range for 5, 50, and 100-yard receiver depths, respectively. Loss differences as great as 30 db are observed. The major differences occur between the two winter profiles. These can be directly attributed to the differences between the surface layers in the two profiles, as discussed earlier.

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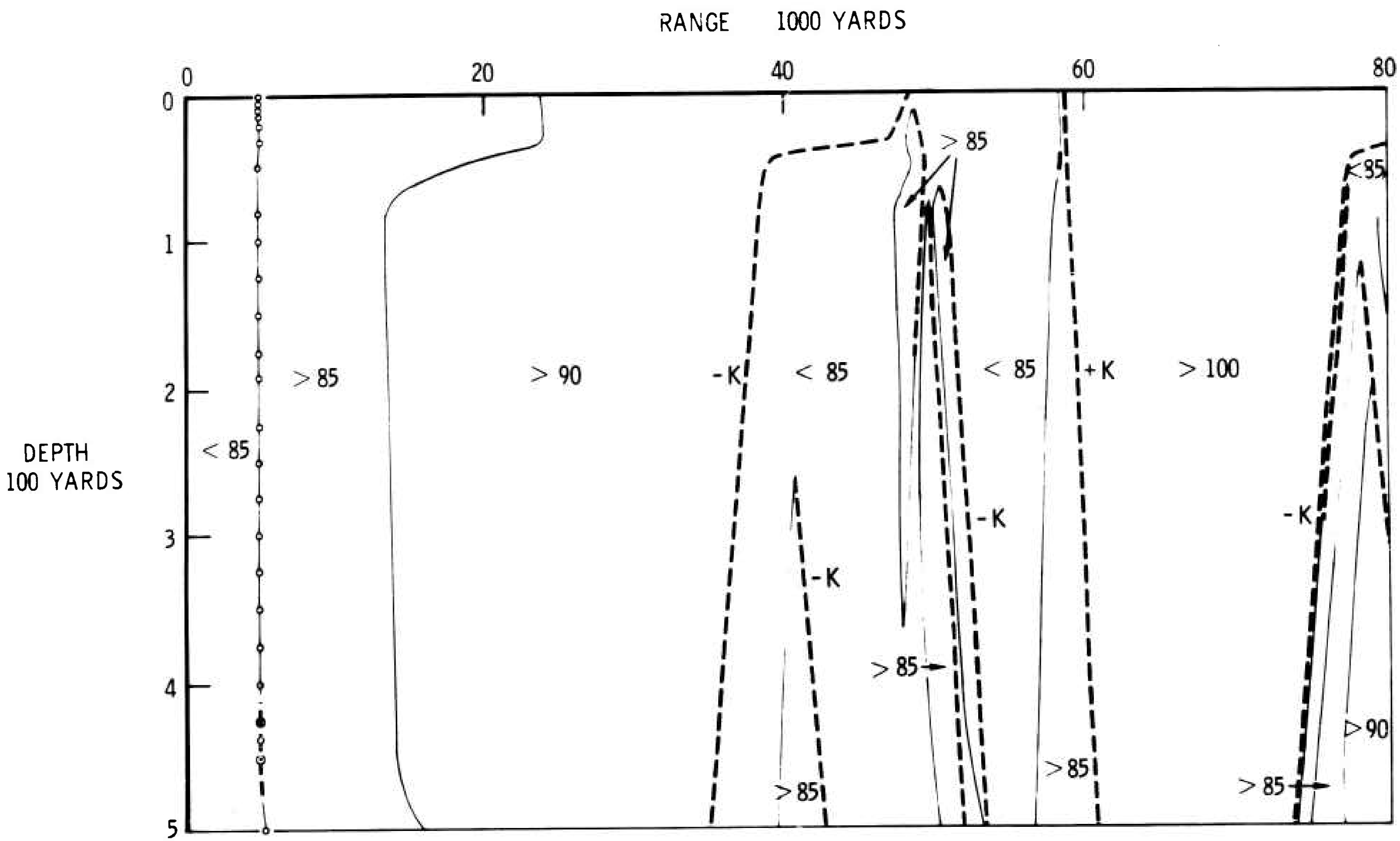

FIGURE 7 - PROPAGATION LOSS IN DB FOR PROFILE OF FIGURE 3, 50 YARD SOURCE DEPTH

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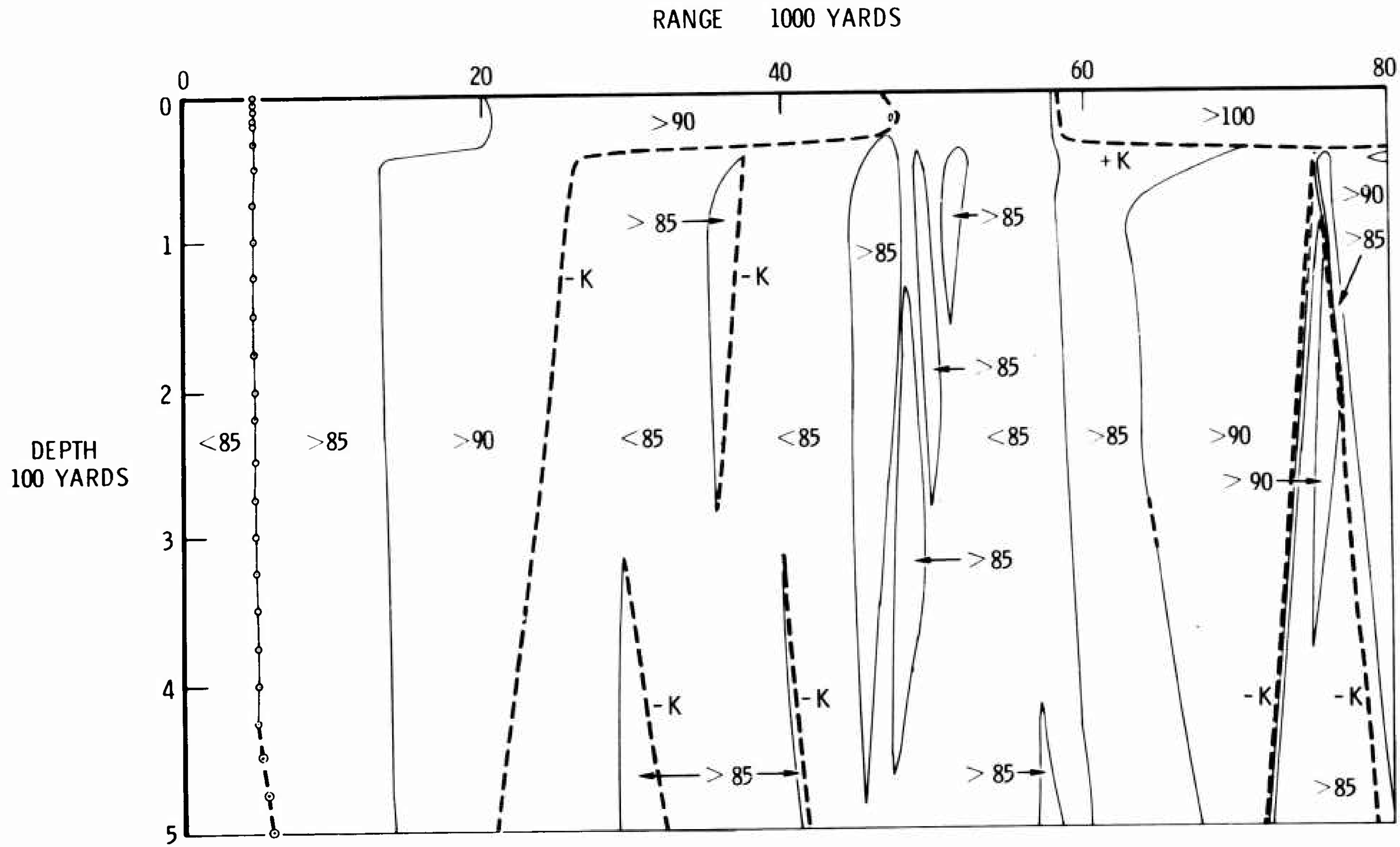

FIGURE 8 - PROPAGATION LOSS IN DB FOR PROFILE OF FIGURE 4, 50 YARD SOURCE DEPTH

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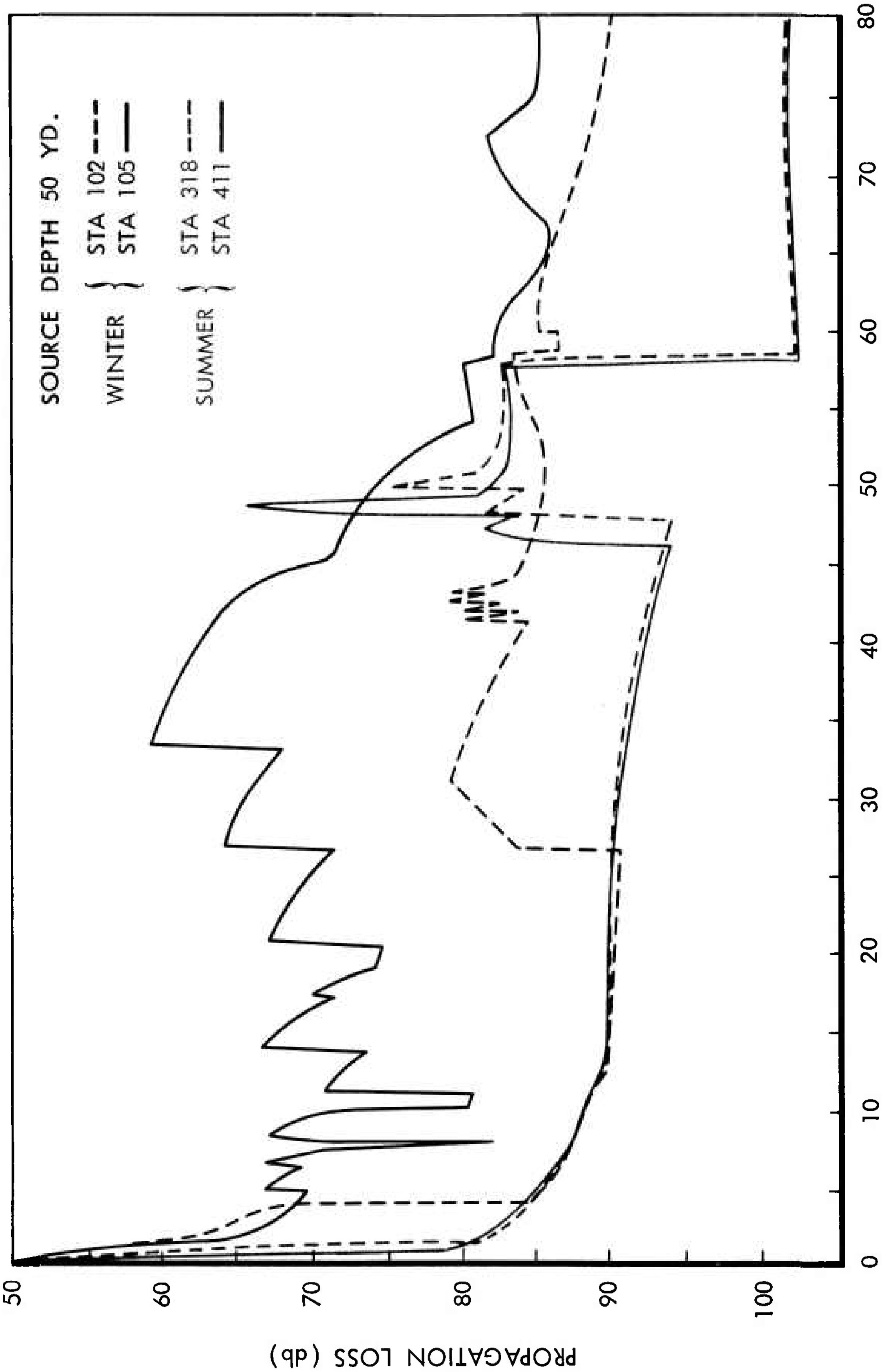

FIGURE 9 - PROPAGATION LOSS FOR 5-YD RECEIVER DEPTH

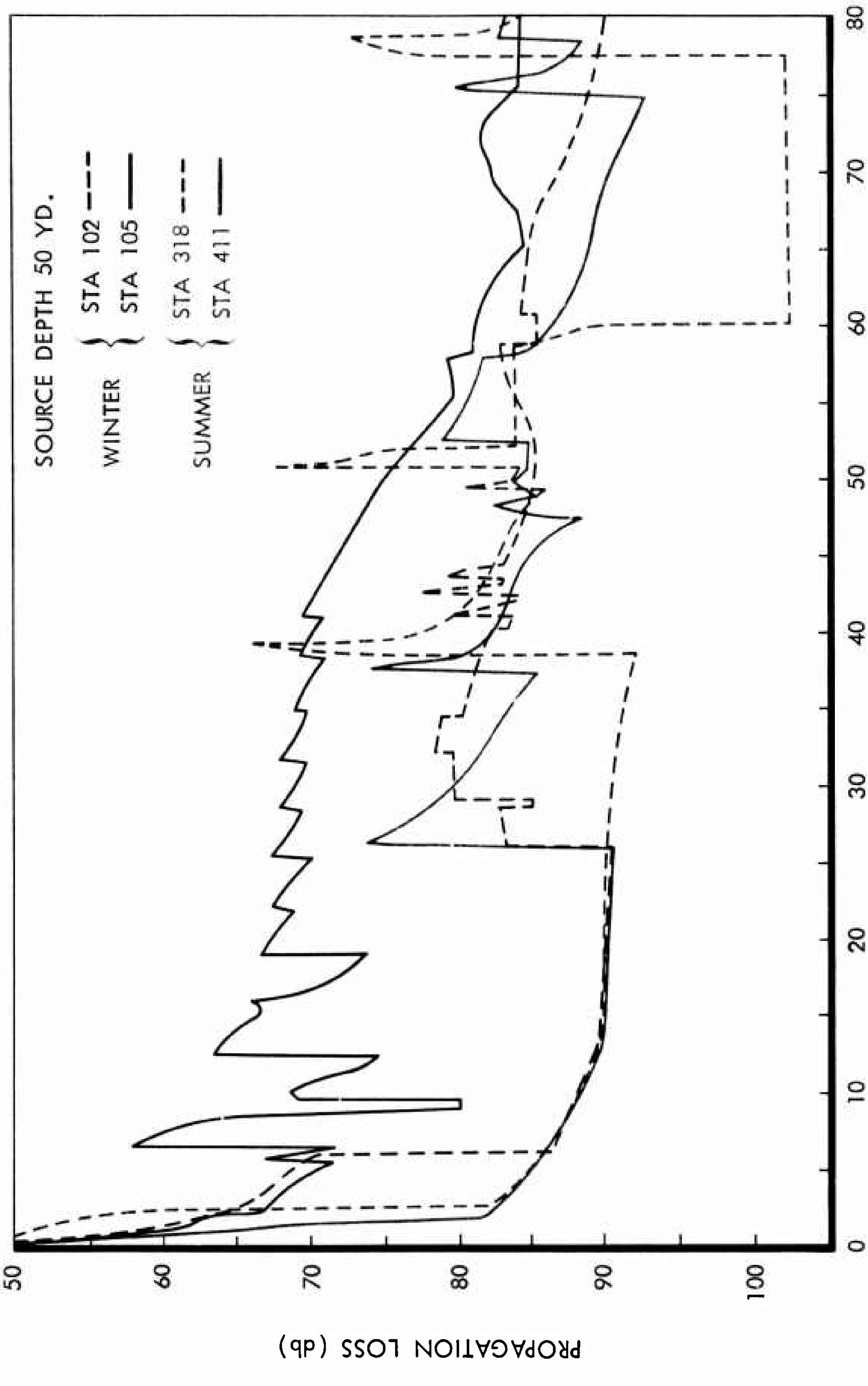

FIGURE 10 - PROPAGATION LOSS FOR 50-YD RECEIVER DEPTH

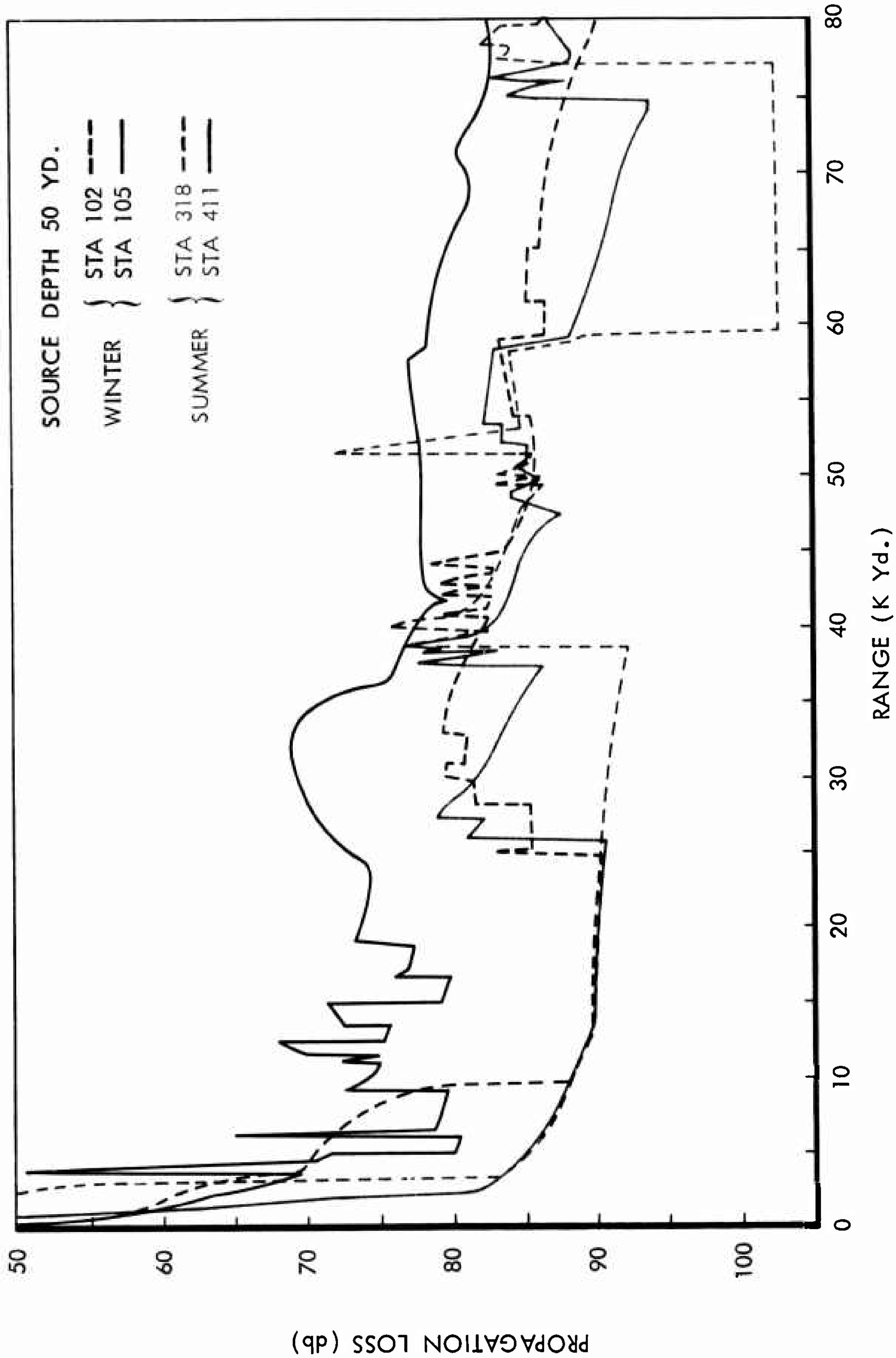

FIGURE 11 - PROPAGATION LOSS FOR 100-YD RECEIVER DEPTH

Section 4

CONCLUSIONS AND RECOMMENDATIONS

This preliminary study has shown that the area in which Ocean Station "PAPA" is located is one of large variability. The four velocity profiles chosen have resulted in significant differences in the propagation loss field. The two winter profiles were taken on the same cruise about 10 days apart in 1962, while the two summer profiles were from different years (1962 and 1963). It must be concluded, therefore, that both short-term and long-term fluctuations in sound velocity profile do significantly affect propagation loss. No direct correlation between differences in propagation loss and the presence of single- or double-velocity minima per se was apparent.

It is recommended that further studies be performed utilizing the available 10 years of Station "PAPA" data to determine the various types of sound velocity profiles and to delineate "the most frequent cases" for forecasting purposes.

Section 5

REFERENCES

1. Pedersen, M. A., 1961; "Acoustic Intensity Anomalies Introduced by Constant Velocity Gradients," Journal Acoustical Society of America, Vol. 33, No. 4, pp. 465-474.

2. Pedersen, M. A., D. F. Gordon, and Alice Joy Keith, 1962; "A New Ray Intensity Procedure for Underwater Sound Based on a Profile Consisting of Curvilinear Segments," U.S. Navy Electronics Laboratory, Report 1105 (Confidential).

3. Gordon, D. F., 1964; "Extensions of the Ray Intensity Procedure for Underwater Sound Based on a Profile Consisting of Curvilinear Segments," U. S. Navy Electronics Laboratory, Report 1217 (Confidential).

4. Lesser, R. M. and K. R. Igelman, 1964; "Computations of Theoretical Ray Intensities and Propagation Losses Utilizing a Curvilinear Sound Velocity Profile," Lockheed-California Company, Report LR 18149 (Confidential).

5. Tabata, S., et. al., 1962; "Oceanography Data Record, Ocean Weather Station "P", January 17 to August 5, 1962," Fisheries Research Board of Canada, Ms Report Series (Oceanographic and Limnological) No. 139.

6. Robertson, D. G., et. al., 1963; "Oceanography Data Record, Ocean Weather Station "P", August 1, 1962 to January 18, 1963," Fisheries Research Board of Canada, Ms Report Series (Oceanographic and Limnological) No. 154.

7. Wilson, W. D., 1960; "Equation for the speed of sound in sea water," Acoustical Society of America, Journal 32, p. 1357.